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DEPARTMENT OF REGISTRATION AND EDUCATION
VERA M. BINKS, *Director*

DIVISION OF THE
STATE GEOLOGICAL SURVEY
JOHN C. FRYE, *Chief*
URBANA

REPORT OF INVESTIGATIONS 188

SANDSTONE RESOURCES OF EXTREME SOUTHERN ILLINOIS

A Preliminary Report

BY

D. L. BIGGS AND J. E. LAMAR

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

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ABSTRACT

Sandstones crop out at many places in extreme southern Illinois. Most of them are light yellow, buff, or brown. Sixty-five samples from 30 outcrops representing 11 geological formations were investigated. Sieve tests revealed that the sands range from fine to coarse grained. The shape of the sand grains varied from angular to subrounded. Chemical analyses of 14 selected samples in the disaggregated, but otherwise unprocessed, state revealed that 11 samples contain more than 95 percent silica; iron oxide ranged from .18 to 4.2 percent. Washing the samples and eliminating the material passing a 270-mesh sieve increased the silica content of 11 samples to above 98 percent and in most cases lowered the iron-oxide content. Washing, acid treatment, and removal of magnetic particles decreased the iron-oxide content of five samples to below .035 percent.

The results suggest that, if properly processed, some southern Illinois sandstones may yield silica sand possibly suitable for a variety of industrial uses. However, test drilling of deposits and testing of resulting samples, together with an evaluation of production costs and available markets, is necessary to demonstrate the uniformity, commercial workability, and economic importance of the deposits.

NUMEROUS OUTCROPS of several sandstone formations having a thickness of 50 feet or more are found in that part of Illinois south of the coal fields. Only limited use is now being made of these sandstones—for small tonnages of building stone. This preliminary investigation was undertaken to determine possible uses for the sandstone in the nonstructural field.

The assistance of John R. Dyni in the field and laboratory work is gratefully acknowledged. Thanks are due also to Juanita Witters and L. D. McVicker of the Illinois Geological Survey's Geochemistry Section who made the spectrographic and chemical analyses.

SANDSTONE FORMATIONS

The geologic "formations" of southern Illinois that are wholly or in part composed of sandstone are listed and underlined below, from youngest to oldest. Limestone and shale formations between the sandstones also are named but not underlined.

<u>Tradewater</u>
<u>Caseyville</u>
Kinkaid
<u>Degonia</u>
Clore
<u>Palestine</u>
Menard
<u>Waltersburg</u>
Vienna
<u>Tar Springs</u>
Glen Dean
<u>Hardinsburg</u>
Golconda
<u>Cypress</u>
Paint Creek
<u>Bethel</u>
Renault
<u>Aux Vases</u>

The Tradewater and Caseyville sandstones are Pennsylvanian; the other formations are Upper Mississippian. The Thebes sandstone, which was sampled in Alexander County, is much older than any of those listed.

GEOLOGIC REPORTS

Much of the area covered has been mapped geologically and published reports are available. Figure 1 shows the area covered by the various reports further identi-

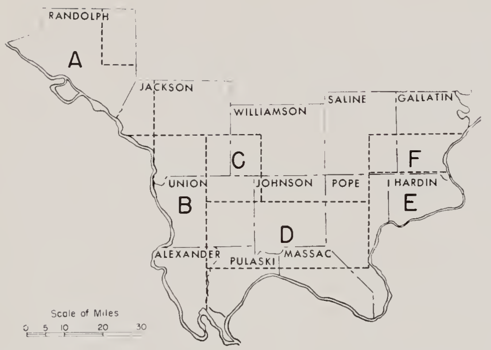

FIG. 1.—Areas covered by geologic reports of the Illinois State Geological Survey.

A. Report of Investigations 59. Preliminary geological maps of the pre-Pennsylvanian formations in part of southwestern Illinois—Waterloo, Kimmswick, New Athens, Crystal City, Renault, Baldwin, Chester, and Campbell Hill quadrangles: Stuart Weller and J. M. Weller; Explanation and stratigraphic summary: J. M. Weller. 1939. 15 p., 3 pls., 2 figs. 25c.

B. Report of Investigations 70. Preliminary geologic map of parts of the Alto Pass, Jonesboro, and Thebes quadrangles in Union, Alexander, and Jackson counties: J. M. Weller and G. E. Ekblaw; Explanation and stratigraphic summary: J. M. Weller. 1940. 26 p., 1 pl., 2 figs. 25c.

C. Bulletin 48. Geology and mineral resources of the Carbondale quadrangle: J. E. Lamar. 1925. 172 p., 5 pls., 28 figs. 50c.

D. Report of Investigations 60. Preliminary geologic map of the Mississippian formations in the Dongola, Vienna, and Brownfield quadrangles: Stuart Weller and F. Krey; Explanation and stratigraphic summary: J. M. Weller. 1939. 11 p., 1 pl., 1 fig. 25c.

E. Bulletin 76. Geology of the fluorspar deposits of Illinois: J. M. Weller, R. M. Grogan, and F. E. Tippie (with contributions by L. E. Workman and A. H. Sutton). 1952. 147 p., 7 pls., 25 figs., 4 tables. $1.00.

F. Bulletin 47. Geology and mineral resources of the Equality-Shawneetown area: Charles Butts. In cooperation with the U. S. Geol. Survey. 1925. 76 p., 3 pls., 6 figs. 50c.

fied above. Details regarding the sandstone formations are given in these reports, which are available from the State Geological Survey, Urbana, Illinois. The salient data in the reports regarding the thickness and character of the sandstone are listed in table 1.

NATURE OF SANDSTONE EXPOSURES

The sandstones that crop out in southern Illinois are all more-or-less weathered from long exposure. Many of them are buff or brown owing to oxidation of iron-bearing minerals in them or to iron compounds that have been introduced into them. In some places relatively recent roadcuts suggest that the intensity of the buff or brown color decreases away from the outcrop. This is further suggested by the records of wells in southern Illinois that report the color of the sandstones as gray or white.

The well data also indicate that some of the Upper Mississippian sandstones contain calcium carbonate some distance from the outcrops. Many of the outcrops are believed to be noncalcareous, or essentially so, but a few samples did contain a small percentage of calcium carbonate. The presence of calcareous material probably is undesirable in sandstone that is to be used as a source of silica sand.

WORKABILITY OF DEPOSITS

In the area covered by this report there are many deposits of sandstone. All the thicker sandstones form bluffs in some places. Overburden on many deposits is only loess, a silty clay. Near the Mississippi and Ohio rivers, the loess is as much as 60 feet thick in some places, but inland its thickness decreases rapidly and is about 5 to 10 feet in the north-central part of the area covered by this report. Judicious selection of quarry sites may materially reduce the average thickness of loess overburden to be stripped from many deposits.

Some sandstone deposits in southern Illinois crop out in bluffs and are overlain by limestone or shale formations in addition to the surficial loess. Such deposits presumably would have to be worked by underground mining.

Underground mining may be preferable for certain sandstone strata having characteristics particularly suitable for certain purposes. This procedure is feasible under proper conditions as demonstrated by the

TABLE 1.—THICKNESS AND GENERAL CHARACTER OF SANDSTONES IN THE AREAS SHOWN IN FIGURE 1

Area	A	B	C	D	E	F
Tradewater		Prob. thick*	Thick*		Thick*	Mod. thick*
Caseyville	Thick locally*	Thick*	Thick*	Thick*	Thick*	Thick*
Degonia	75-100′*	Max. 75′	60–125′	100′ or less*	35′†	X
Palestine	40–60′*	30′*	35–50′*	40–80′*	60′*	60′*
Waltersburg	X	45′*†	0–30′*	30–70′	25–40′†	X
Tar Springs	X	75′	50–100′*	40–100′†	90′±*	100–150′*
Hardinsburg	X	Max. 40′*†	20–30′*	30–100′†	70–120′*	30–50′
Cypress	X	Max. 50′†	70–80′*	100′+	80–120′ }	200′+
Bethel	X	X	5–10′	15–130′	60–100′ }	
Aux Vases	80′	X	X	X	X	X
Thebes	X	75–100′+*	X	X	X	X

X—absent, not well developed, not identified, or does not crop out.
*—part or parts of the formation are thin-bedded or shaly.
†—in places much or all of the formation is shaly.

underground mining of sandstone for silica sand in other areas.

TESTING OF DEPOSITS

Before commercial development is undertaken, test drilling or other exploration of deposits is recommended to determine the physical and chemical character of the unweathered sandstone and to obtain detailed information on thickness of overburden, possible presence of shale partings, calcareous zones, and other data related to the proper development of the deposit.

SAMPLES

Twenty-eight deposits, representing each of the principal sandstone formations in extreme southern Illinois, were carefully sampled at one or more places from road cuts and outcrops, by taking chunks at vertical intervals ranging between one and five feet. The deposits sampled are not necessarily those that may prove desirable for development should the sandstones have commercial importance; the representative outcrops sampled were those that gave a maximum exposure of sandstone as little weathered as possible. Road cuts were preferred because the sandstone exposed in them was generally fresher than the stone in natural outcrops. Nevertheless, all the deposits sampled were more-or-less weathered, and many were buff or brown.

The location and numbers of the sampled deposits are shown in figure 2. Description of these deposits follows.

DEPOSITS SAMPLED

1

Cen. SE¼ SW¼ sec. 30, T. 12 S., R. 1 E., along south bank Cypress Creek, SE of Anna, Union Co. Cypress sandstone. 25 ft. brown, cream, and pinkish sandstone in irregular, mostly thick beds.

Sample 1A, upper 12½ ft.; 1B, lower 12½ ft.

2

Cen. E½ W½ E½ sec. 36, T. 9 S., R. 4 W., in gully in Fountain Bluff near Gorham, Jackson Co., near Illinois Central and Missouri Pacific railroads. Caseyville sandstone. Exposure consists of:

73 ft.—coarse-grained brown sandstone, in thick beds, with irregular iron-cemented bands. These bands may not be present in the unweathered sandstone. Sample 2A.

15 ft.—coarse-grained brown sandstone, one solid bed, a few pebbles. Sample 2B.

17½ ft.—medium-grained brown sandstone. Sample 2C.

30 ft.—coarse-grained brown slightly limy sandstone. Sample 2D.

35 ft.—fine-grained brown slightly limy sandstone. Sample 2E.

Covered.

The iron-oxide content of the sandstone at this place probably is higher than at some other places in the bluff. Exposures of sandstone in the west side of the bluff appear to be lower in iron oxide.

3

Cen. E½ W½ NW¼ sec. 20, T. 11 S., R. 1 W., road cut north of Cobden, Union Co., near Illinois Central Railroad. Degonia sandstone. 14 ft. white, brown, and red mottled sandstone. Sample 3.

4

NW¼ NW¼ SW¼ sec. 1, T. 12 S., R. 1 W., road cut southwest of Saratoga, Union Co. Tar Springs sandstone. 33 ft. brown, buff, and red sandstone. Underlain by 4 ft. dark-gray shale.

Sample 4A, top 16½ ft.; 4B, lower 16½ ft.

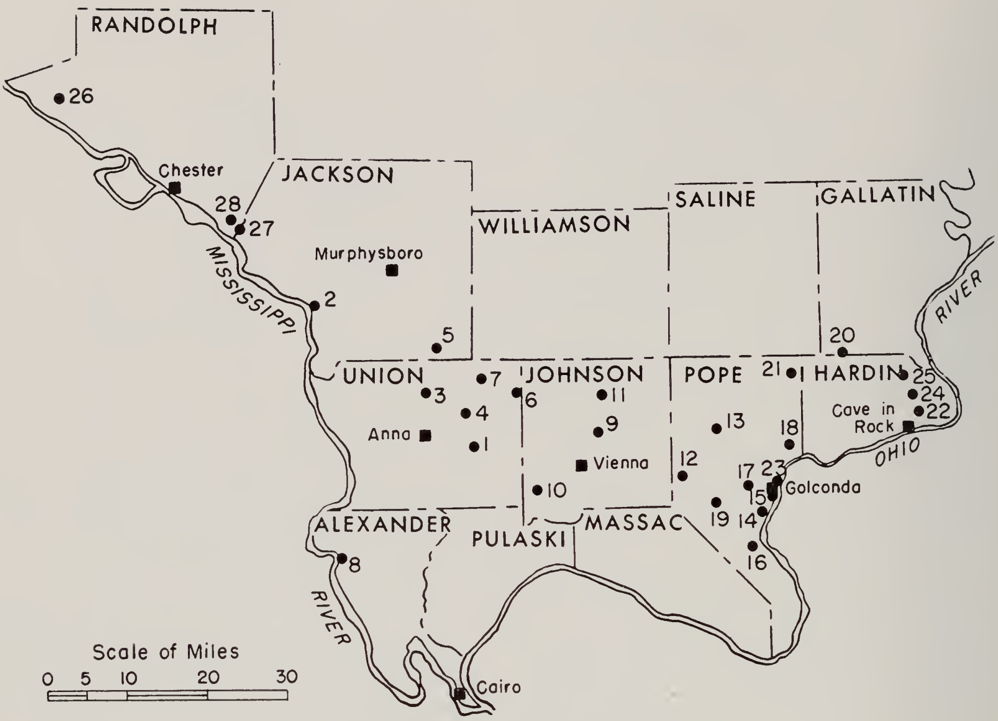

Fig. 2.—Locations of sandstone outcrops sampled.

5

SW¼ SE¼ SW¼ sec. 28, T. 10 S., R. 1 W., in gully and road cut near Makanda, Jackson Co., near Illinois Central Railroad. Caseyville sandstone. Strata exposed are:

14 ft.—brown sandstone.
12 ft.—coal, shale, and carbonaceous sandstone.
14 ft.—gray and white sandstone.
2 ft.—shale.
Sample 5A, upper 14 ft.; 5B, lower 14 ft.

6

N½ SE¼ NW¼ sec. 24, T. 11 S., R. 1 E., in road gutter near Lick Creek, Union Co. Caseyville sandstone. 45 ft. fine-grained white and buff sandstone. Sample 6A, upper 19 ft.; 6B, middle 19 ft.; 6C, basal 7 ft.

7

E½ SE¼ SE¼ sec. 17, T. 11 S., R. 1 E., in steep gully near Progress, Union Co. Caseyville sandstone. 48 ft. soft brown sandstone. Sample 7A, upper 13 ft.; 7B, next lowest 4 ft.; 7C, next lowest 18 ft.; 7D, lower 9 ft. Basal 4 ft. too dirty to sample.

8

NE¼ NW¼ sec. 4, T. 15 S., R. 3 W., along Illinois 3 at Gale, Alexander Co., near Missouri Pacific and C. & E. I. railroads. Thebes sandstone. 20 ft. limy sandstone which weathers to thin beds. Upper 3 ft. brown, lower 17 ft. gray. Sample 8.

9

Cen. E½ E½ sec. 15, T. 12 S., R. 3 E., road cut on U. S. 45 near Bloomfield, Johnson Co., near C. C. C. & St. Louis Railroad. Caseyville sandstone. 35 ft. coarse-grained white and cream sandstone. Sample 9A, top 11 ft.; 9B, next lowest 8 ft.; 9C, next lowest 11 ft.; 9D, basal 5 ft.

10

NW cor. SE¼ NW¼ sec. 20, T. 13 S., R. 2 E., road cut along Illinois 37 at north edge of Cypress and adjacent gully, Johnson Co., near C. & E. I. Railroad. Cypress sandstone. Exposure consists of:

22 ft.—white or cream friable sandstone, locally iron-stained—road cut. Sample 10A, top 10 ft.; 10B, lower 13 ft.
5½ ft.—covered interval.
27½ ft.—yellow friable sandstone, in gully below road cut. Sample 10C.

11

SE¼ NW¼ sec. 27, T. 11 S., R. 3 E., in gully near Tunnel Hill, Johnson Co. Probably Tradewater sandstone. 54 ft. brown, reddish, and white well-cemented sandstone. Sample 11A, upper 27 ft.; 11B, lower 27 ft.

12

W½ SE¼ sec. 17, T. 13 S., R. 5 E., in road cut along Illinois 146 near Dixon Springs, Pope Co. Palestine sandstone. 23 ft. of white, brown, and pinkish well-cemented sandstone. Sample 12A, upper 11½ ft.; 12B, lower 11½ ft.

13

N½ SW¼ sec. 13, T. 12 S., R. 5 E., near Glendale in a cut made in 1948 along road between Eddyville and Glendale, Pope Co. Caseyville sandstone. Exposure consists of:

14 ft.—white and tan fine-grained sandstone with about 3 ft. of interbedded shale. Sample 13A; does not include shale.
44 ft.—covered; probably sandstone.
9 ft.—tan sandstone. Sample 13B.
5 ft.—covered.
8 ft.—tan sandstone, Sample 13C.
6 ft.—tan sandstone, Sample 13D.

14

SW¼ SW¼ NW¼ sec. 11, T. 14 S., R. 6 E., in road gutter near Homberg, Pope Co. Cypress sandstone. 20 ft. brown sandstone in weathered outcrop. Sample 14A, top 11 ft.; 14B, lower 9 ft., which is slightly limy.

15

NW¼ NE¼ SW¼ sec. 30, T. 13 S., R. 7 E., abandoned quarry along Ohio River at Golconda, Pope Co. Cypress sandstone. 44 ft. of friable white or cream sandstone with brown specks and streaks. Sample 15A, top 11 ft.; 15B, middle 18 ft.; 15C, lower 15 ft.

16

SE¼ SW¼ NE¼ sec. 34, T. 14 S., R. 6 E., in road gutter north of Bay City, Pope Co. Bethel sandstone. Exposure consists of:

9½ ft.—white sandstone with iron-stained streaks.
5 ft.—covered interval.
20 ft.—buff, tan, and white sandstone.
Sample 16A, top 3½ ft.; 16B, next lowest 9 ft. of sandstone exposed; 16C, the next lowest 12 ft.; 16D, the bottom 5 ft.

17

SW¼ SW¼ sec. 22, T. 13 S., R. 6 E., in road cut near Waltersburg, Pope Co. Tar Springs sandstone. 21½ ft. white or cream sandstone; iron-stained in places. Sample 17.

18

N½ NW¼ NE¼ sec. 28, T. 12 S., R. 7 E., in road cut northwest of Shetlerville, Pope Co. Hardinsburg sandstone. Exposure consists of:

2½ ft.—white and tan sandstone. Sample 18A.
5 ft.—covered interval.
15 ft.—white firmly cemented sandstone with some brown iron streaks. Sample 18B.

19

NE cor. SE¼ sec. 36, T. 13 S., R. 5 E., bluff at Brownfield, Pope Co., near Illinois Central Railroad. Hardinsburg sandstone. 24 ft. slightly limy white and tan sandstone. Sample 19.

20

SE cor. SE¼ SW¼ sec. 33, T. 10 S., R. 8 E., at High Knob near fire tower, near Karbers Ridge, Gallatin Co. Probably mostly Caseyville sandstone. Strata exposed are:

12 ft.—medium- to coarse-grained white or pinkish sandstone, in places conglomeratic. Sample 20A.
9 ft.—coarse-grained mostly white sandstone. Lower 5 ft. contains hard white particles which may be chert. Sample 20B.
14½ ft.—medium-grained sandstone. Top 8½ ft. white, lower 6 ft. yellow and red. Sample 20C.
8 ft.—conglomeratic coarse-grained red and purplish sandstone. Sample 20D.

21

S½ N½ N½ sec. 9, T. 11 S., R. 7 E., in bluff along road near Herod, Pope Co. Caseyville sandstone. Strata exposed are:

25 ft.—mostly coarse-grained gray and brown sandstone. Sample 21A.
21½ ft.—medium-grained sandstone. Sample 21B.
10½ ft.—coarse-grained iron-stained sandstone. Sample 21C.

22

NE¼ SW¼ SW¼ sec. 1, T. 12 S., R. 9 E., overburden on quarry north of Cave in Rock, Hardin Co. Bethel sandstone. 35½ ft. of fine- and medium-grained cream, white, and yellow sandstone. Sample 22A, from upper 18 ft.; 22 B, lower 17½ ft.

23

W½ SE¼ sec. 18, T. 13 S., R. 7 E., in bluff of Ohio River a short distance north of Golconda, Pope Co. Hardinsburg sandstone. 27 ft. of fine-, medium-, and coarse-grained white and tan sandstone, in places yellow or brown. Sample 23.

24

Cen. S½ sec. 25, T. 11 S., R. 9 E., in road cut near Cave in Rock, Hardin Co. Hardinsburg sandstone. 21 ft. white and yellow sandstone. Sample 24A, from upper 9 ft. of outcrop; 24B, from lower 12 ft.

25

NE¼ NE¼ sec. 10, T. 11 S., R. 9 E., in road cut near Cadiz, Hardin Co. Tradewater sandstone. 20 ft. of fine- to coarse-grained mostly brown sandstone. Sample 25.

26

1.6 miles northwest of Modoc in bluff on south side of mouth of Barbeau Hollow, on Modoc–Prairie du Rocher road, Randolph Co., near Missouri Pacific Railroad. Aux Vases sandstone. This area is not surveyed into sections. 83 feet of sandstone, the upper 35 ft. tan, the lower 48 ft. somewhat whiter. Sample 26A, from the top 31 ft. of sandstone; 26B, from the lower 52 ft.

27

N½ SE¼ sec. 17, T. 8 S., R. 5 W., in bluff near Cora, Randolph Co., near Missouri Pacific Railroad. Degonia sandstone. 31 ft. brown sandstone. Sample 27.

28

NW¼ NW¼ NE¼ sec. 18, T. 8 S., R. 5 W., bluff at Rockwood, Randolph Co., near Missouri

Pacific Railroad. Palestine sandstone. 34 ft. tan sandstone in beds 6-13 ft. thick, separated by shaly layers up to 6 inches thick. Shale not included in sample 28 from this outcrop.

29

NW¼ SE¼ SW¼ sec. 11, T. 11 S., R. 7 E., Hardin Co., east of Herod. Bethel sandstone. Diamond drill core. Sample from depth of 622 to 659 feet.

30

Same location as 29. Cypress sandstone. Sample from depth of 485 to 535 feet.

31

Same location as 29. Hardinsburg sandstone. Sample from depth of 285 to 312 feet.

32

Same location as 29. Tar Springs sandstone. Sample from depth of 85 to 108 feet.

LABORATORY PREPARATION OF SAMPLES

The samples taken from an outcrop were examined, disaggregated, and grouped into one or more "composite" samples on the basis of grain size. Thus, if an outcrop consisted of 30 feet of coarse-grained sandstone and 20 feet of fine-grained sandstone, the field samples from the upper 30 feet were combined, in amounts proportionate to the thickness of sandstone they represent, into a single composite sample. The samples from the lower 20 feet of sandstone would be similarly combined.

DISAGGREGATION OF SANDSTONE

No difficulty was experienced in disaggregating the sandstone samples with a mortar and pestle. However, to obtain rough quantitative data on what might be expected from mechanical equipment, seven samples were treated as follows. About 500 grams of each sample was put through a laboratory jaw-crusher set at about 1/8 inch. A 50-gram sample of the crusher product was split out and sieved. The remainder was passed through a pair of laboratory rolls set at 1/16 inch for coarse sands, 1/32 inch for medium-grained sands, and set tight for fine sands. A 50-gram sample was split out and sieved. Another 50-gram sample was split out and processed in a mortar and pestle. A reasonably complete disaggregation results from the latter procedure.

The results of sieve tests on samples processed as described above revealed no differences of more than 5 percent between those disaggregated by mortar and pestle and those by the rolls only. Much closer agreement was evident for most sieve sizes, especially in the case of the medium- and fine-grained sandstones.

It is concluded from these tests that a reasonable degree of disaggregation of the outcropping sandstones probably is possible by mechanical means.

MINERAL COMPOSITION

The predominant component of the sand samples is quartz (silicon dioxide). Iron-oxide minerals (such as limonite) and clay occur in varying though commonly comparatively small amounts. A few samples also contain a relatively small amount of calcite. Very small amounts of other minerals were noted. These minerals are called heavy minerals because their specific gravity is greater than that of quartz. Information on the kind and approximate amount of these minerals in seven samples is given in table 2.

Table 2.—Heavy Minerals in Sands

	2A	2C	9C	10B	15B	24B	26B
Total weight percent of heavy minerals							
	.09	.09	.13	.03	.2	.18	.1
Abundance*							
Leucoxene	A	A	A	A	A	A	A
Zircon	C	A	VC	A	A	A	A
Ilmenite	VC	VC	R	C	VC	C	C
Rutile	VR	VC	C	VC	C	C	R
Tourmaline	C	C	VC	VC	C	VC	C
Garnet	R			R	R		VR
Anatase					R	R	VC
Hornblende							VR
Topaz						VR	
Zoisite		VR					
Muscovite	R		VC				
Hematite						VR	

*A, abundant; VC, very common; C, common; R, rare; VR, very rare.

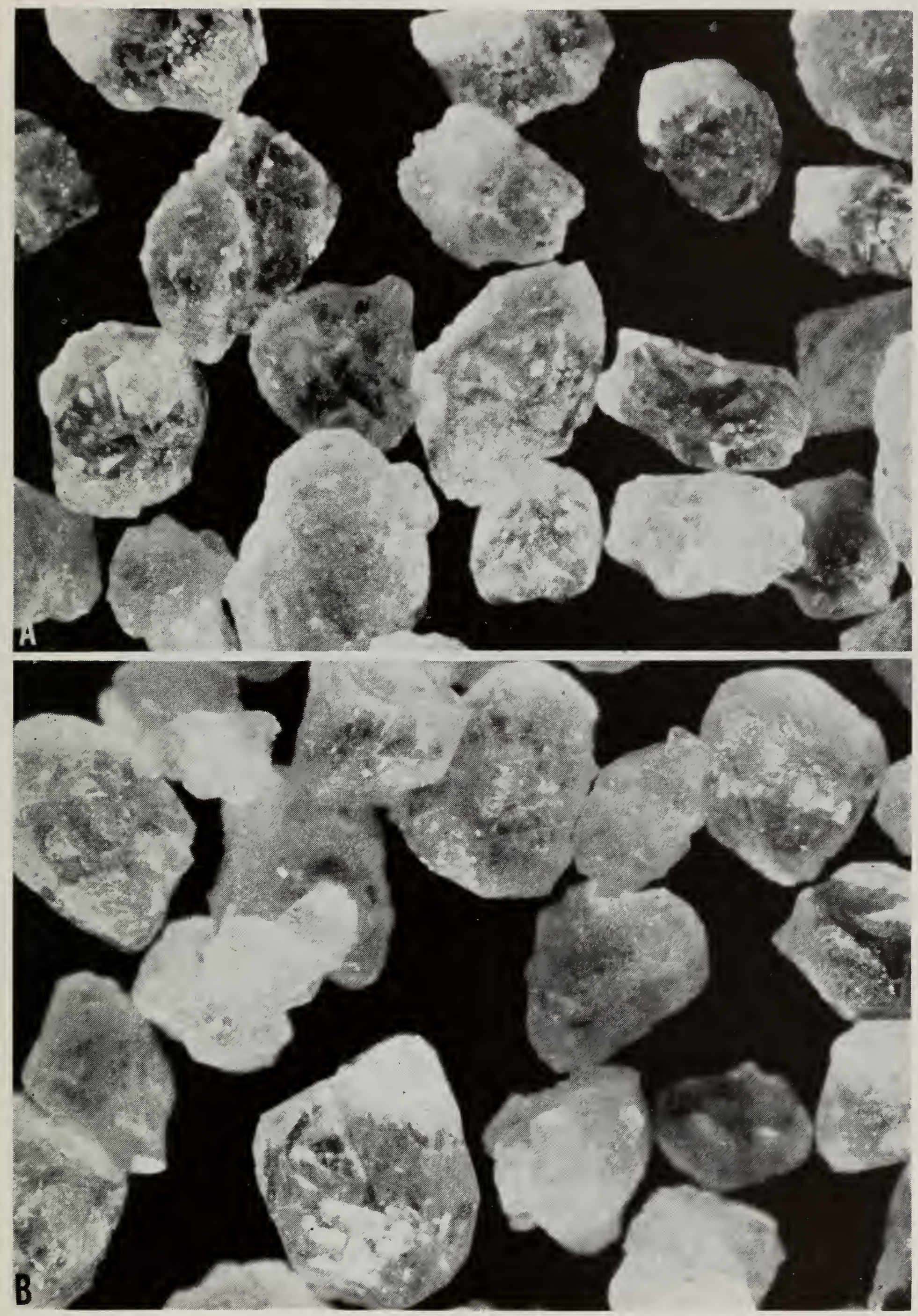

Plate 1.—A. Bethel sandstone, 35 by 65 mesh. Sample 16C. × 80.
B. Caseyville sandstone, 28 by 65 mesh. Sample 9B. × 55.

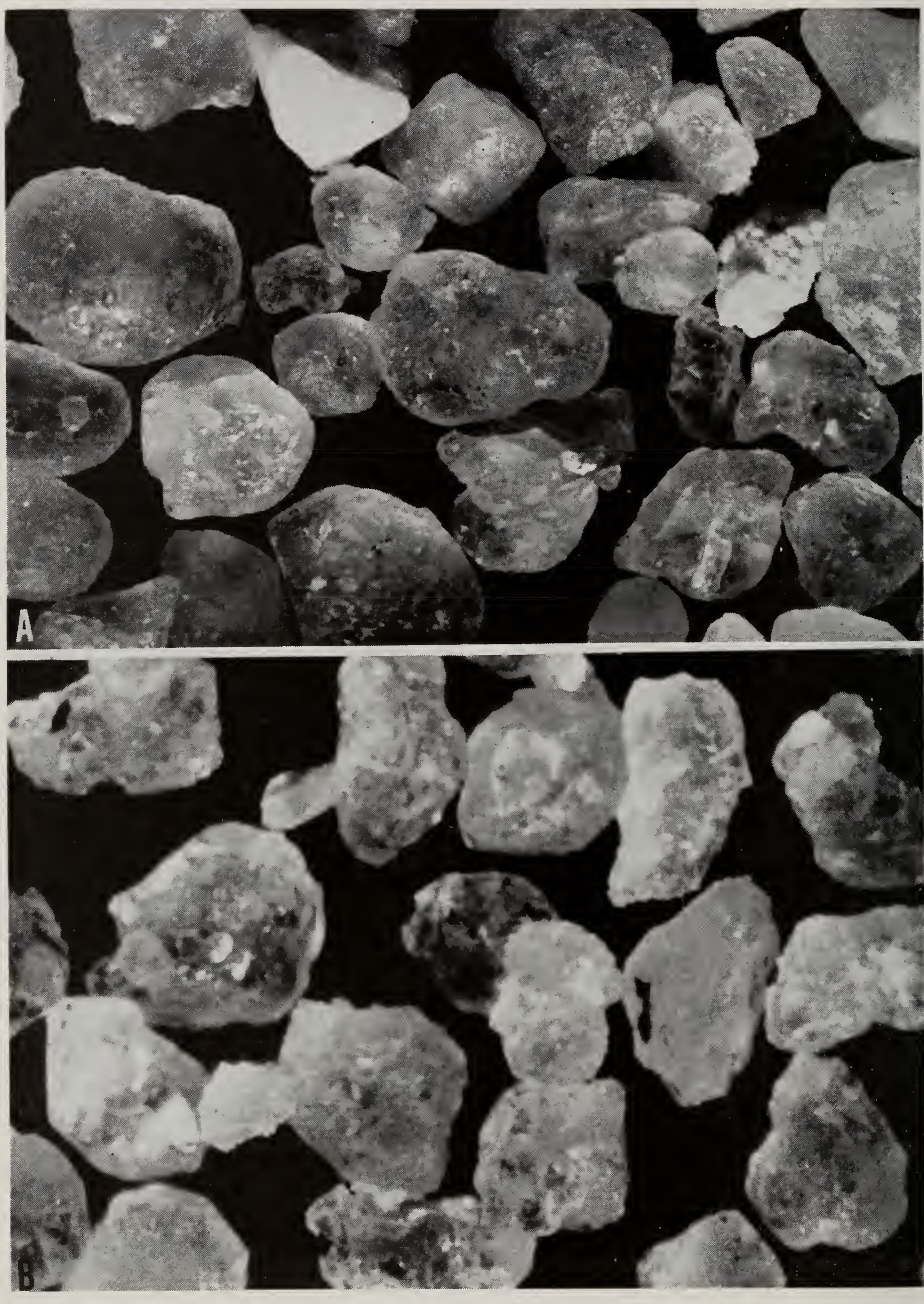

Plate 2.—A. Coarse-grained Caseyville sandstone. Sample 2B. × 22.
B. Probably Tradewater sandstone, 48 by 65 mesh. Sample 11A. × 80.

GRAIN SHAPE

All the fine-grained sands studied have angular grains; the grains in the medium- and coarse-grained sands are more rounded but probably none of the sands can be classified commercially as "round grain" sands (pls. 1 and 2). The secondary enlargement of sand grains by the addition of quartz is evident in many samples; some samples contain grains that are almost perfect quartz crystals. Data covering a visual estimate of the grain shape of the samples otherwise investigated are given in table 3.

SIEVE TESTS

Sieve tests were made on each composite sample. The first step was disaggregation of the sandstone into its constituent particles. This was done by crushing it mechanically to about 1/4 inch and then rubbing gently in the mortar with frequent hand sieving to remove the discrete sand grains. It is believed that relatively few grains were broken during disaggregation. In the coarser sieve sizes of a given sand, one particle out of about 200 was made up of two or, rarely, more sand grains. In the finer sizes, disaggregation appeared to be even more nearly complete.

Table 3.—Grain Shape of Sands

Very angular

Samples 5A, 5B, and 8.

Angular

Samples 1B, 3, 4A, 4B, 7B, 7C, 7D, 11A, 11B, 12A, 12B, 13A, 13B, 13D, 14A, 14B, 15B, 15C, 18A, 18B, 21A, 21C, 23, 24A, 25, 26A, 26B, 27, 28.

Subangular

Samples 1A, 6A, 6B, 6C, 7A, 9A, 10A, 10C, 13C, 15A, 16A, 16B, 16C, 16D, 17, 19, 21B, 22A, 22B, 24B.

Subrounded

Samples 9B, 9C, 10B, 20D.

Coarse grains subrounded; fine grains angular

Samples 2A, 2B, 2C, 2D, 2E, 9D, 20A, 20B, 20C.

The disaggregated samples were shaken with water for one hour in an end-over-end shaker and then wet-screened on a 325-mesh sieve. The oversize was dried and screened on Tyler Standard Screen Scale sieves in a Rotap shaker for 10 minutes. The amount of minus-two micron material in the samples was determined by means of the hydrometer procedure. Clay, as defined by the American Foundrymen's Society, was determined by procedures specified by that society.

Results of sieve tests are given in table 4 together with grain fineness numbers calculated in accordance with the procedure set up by the American Foundrymen's Society.

CHEMICAL ANALYSES

It was not feasible to make detailed chemical analyses of all samples taken during the investigation. However, 14 outcrop samples were selected to represent the various sandstone formations exposed in southern Illinois and the variations in grain size. On the basis of these data, it was felt that the general commercial possibilities of the sandstones could be assessed, leaving more extended or additional analyses to those interested in specific deposits.

In addition to the outcrop samples, analytical data also are given of four diamond drill core samples to indicate the nature of the sandstone at a considerable distance back from the outcrop.

Samples were prepared for analysis in three ways:

1) Crude sandstone.—Portions of the disaggregated sandstone prepared for sieve analyses were used. Silica was determined by wet gravimetric chemical analysis; other data spectrographically.

2) Washed +270-mesh sand.—Portions of the disaggregated sandstone prepared for sieve analyses were used. Processing involved washing the sand in a laboratory "squirrel-cage" type scrubber and wet-sieving on a 270-mesh sieve. All chemical data were determined spectrographically except silica, which was determined by difference.

Table 4.—

Sample	County	Near	Thickness, feet	¼	¼	¼	sec.	T.	R.	4	6	8	10	14
										Thebes Sandstone				
8	Alexander	Gale	20		NE	NW	4	15S	3W					
										Aux Vases sandstone				
26A	Randolph	Modoc	31	1.6 miles NW of Modoc				5N	9W					
26B			52											
										Bethel sandstone				
16A	Pope	Bay City	3½	SE	SW	NE	34	14S	6E					
16B			9											
16C			12											
16D			5											
22A	Hardin	Cave in Rock	18	NE	SW	SW	1	12S	9E					
22B			17½											
										Cypress sandstone				
1A	Union	Anna	12½	cen.SE¼	SW		30	12S	1E					
1B			12½											
10A	Johnson	Cypress	10	NW cor.	SE	NW	20	13S	2E					
10B			13											
10C			27½											
14A	Pope	Homberg	11	SW	SW	NW	11	14S	6E					
14B			9											
15A	Pope	Golconda	11	NW	NE	SW	30	13S	7E					
15B			18											
15C			15											
										Hardinsburg sandstone				
18A	Pope	Gowins	2½	N½	NW	NE	28	12S	7E					
18B			15											
19	Pope	Brownfield	24	NE cor.	SE		36	13S	5E					
23	Pope	Golconda	27	W½	SE		18	13S	7E					
24A	Hardin	Cave in Rock	9	cen. S½			25	11S	9E					
24B			12											
										Tar Springs sandstone				
4A	Union	Saratoga	16½	NW	NW	SW	1	12S	1W					
4B			16½											
17	Pope	Waltersburg	21½	SW	SW		22	13S	6E					
										Palestine sandstone				
12A	Pope	Dixon Springs State Park	11½	W½	SE		17	13S	5E					
12B			11½											
28	Randolph	Rockwood	34	NW	NW	NE	18	8S	5W					
										Degonia sandstone				
3	Union	Cobden	14	cen. E½	W½	NW	20	11S	1W					
27	Randolph	Cora	31	N½	SE		17	8S	5W					
										Caseyville sandstone				
2A	Jackson	Gorham	73	cen. E½	W½	E½	36	9S	4W			0.1	0.2	1.3
2B			15									0.1	0.8	7.4
2C			17½									0.1	0.5	0.2

Sieve Tests

Mesh size—Percent retained														Sample
20	28	35	48	65	100	150	200	270	325	$+2\mu$*	-2μ*	A.F.S. clay*	G.F.N.*	
				5.8	11.3	8.2	10.0	21.9	8.9	33.3	0.6	4.0	201	8
	0.3	0.1	0.1	4.5	40.8	36.3	8.5	.9	1.1	6.4	1.0	5.8	95	26A
				10.3	60.0	19.8	4.2	.4	1.1	3.4	0.8	4.2	80	26B
				8.6	51.0	19.4	12.2	1.4	2.2	3.0	2.2	5.0	91	16A
	0.4	2.4	27.1	53.0	13.2	0.4	0.8	0.0	0.0	1.0	1.7	2.0	52	16B
	0.7	3.3	30.2	36.3	12.1	5.2	5.2	1.0	1.4	2.9	1.7	4.0	63	16C
	0.2	2.9	32.1	47.2	13.3	0.3	0.9	0.0	0.0	2.0	1.1	2.0	53	16D
	0.2	19.0	30.6	19.4	14.8	8.7	1.5	0.8	1.5	1.7	1.8	3.2	58	22A
	1.3	6.0	32.4	36.7	18.0	1.8	1.6	0.0	0.0	0.9	1.3	1.6	53	22B
0.1	0.1	0.1	0.1	6.4	45.5	33.7	7.2	0.9	1.0	2.5	2.4	4.0	90	1A
				5.2	46.4	34.0	7.1	0.7	1.2	3.5	1.9	4.2	91	1B
	0.2	0.2	10.7	24.0	38.0	15.3	4.6	1.0	0.8	2.4	2.8	3.3	77	10A
	0.2	0.2	6.8	49.2	34.2	4.7	2.0	0.1	0.4	1.4	0.8	1.2	64	10B
		0.2	2.6	38.7	45.5	6.1	3.3	0.2	0.2	1.7	1.5	2.4	68	10C
			0.2	8.6	44.1	31.2	7.6	0.4	1.4	4.5	2.0	4.9	91	14A
			0.2	5.9	32.1	37.3	12.3	2.3	2.5	5.6	1.8	5.2	104	14B
				9.0	48.5	27.9	7.1	1.0	1.3	3.2	2.0	4.7	88	15A
				9.2	50.2	26.0	5.4	0.8	1.4	5.1	1.9	3.8	92	15B
				10.9	47.4	26.1	7.9	.9	2.0	2.5	2 3	4.1	89	15C
			0.1	5.0	11 3	22.6	30.5	6.8	10.3	10.9	2.5	7.5	149	18A
				3.7	25.0	30.2	19.7	9.0	4.1	6.2	2.1	7.5	119	18B
				15.7	55.1	18.7	5.3	.2	1.1	1.9	2.0	2.5	82	19
			1.6	22.7	47.0	17.9	4.4	0.6	0.6	3.5	1.7	3.9	79	23
		0.2	0.2	6.7	37.1	41.0	9.0	0.9	1.1	2.6	1.2	3.0	93	24A
				8.2	51.4	28.3	5.7	1.1	1.3	3.1	0.9	2.9	88	24B
			2.0	29.1	48.2	11.8	2.9	0.4	0.2	3.2	2.2	4.6	72	4A
			4.5	44.3	38.3	6.3	3.7	0.2	0.2	0.1	2.4	2.4	65	4B
				8.7	56.4	23.6	5.2	0.9	1.1	2.5	1.6	4.0	83	17
		0.2	1.8	5.6	30.8	34.2	14.1	2.1	2.7	6.2	2.3	4.4	108	12A
		0.2	0.2	9.2	34.8	26.3	13.2	3.0	5.7	5.4	2.0	3.2	113	12B
				4.9	20.5	38.8	19.2	2.7	3.7	8.7	1.5	7.4	116	28
				5.3	29.6	37.6	14.5	2.5	4.0	5.0	1.5	5.7	107	3
				4.0	18.0	32.9	24.4	4.0	5.9	8.9	1.9	7.2	127	27
10.4	61.1	13.5	2.0	1.2	2.2	1.3	1.2	0.2	0.1	3.9	1.3	2.1	34	2A
16.9	20.8	9.6	6.9	8.4	13.5	6.6	2.5	0.4	0.5	4.5	1.1	1.5	51	2B
1.1	8.7	8.3	10.9	18.3	27.2	13.0	5.0	0.8	1.1	2.5	2.3	2.6	70	2C

Table 4.—

Sample	County	Near	Thick-ness, feet	¼	¼	¼	sec.	T.	R.					
										4	6	8	10	14
2D			30									0.8	1.1	2.4
2E			35										0.1	0.1
5A	Jackson	Makanda	14	SW	SE	SW	28	10S	1W					
5B			14											
9A	Johnson	Bloomfield	11	cen. E½	E½		15	12S	3E				0.2	0.2
9B			8								1.6	0.2	0.0	0.6
9C			11								1.5	0.0	0.2	0.2
9D			5							6.0	0.8	1.3	1.1	1.0
13A	Pope	Glendale	14	N½	SW		13	12S	5E					
13B			9											
13C			8											
13D			6											
21A	Pope	Herod	25	S½	N½	N½	9	11S	7E					
21B			21½											
21C			10½											
6A	Union	Lick Creek	19	N½	SE	NW	24	11S	1E					
6B			19											
6C			7											
7A	Union	Progress	13	E½	SE	SE	17	11S	1E					
7B			4											
7C			18											
7D			9											
										Tradewater sandstone				
20A	Gallatin	Karbers Ridge	12	SE cor.	SE½	SW	33	10S	8E					
20B			9											
20C			14½											
20D			8											
25	Hardin	Cadiz	20		NE	NE	10	11S	9E					
11A	Johnson	Tunnel Hill	27		SE	NW	27	11S	3E					
11B			27											

*+2μ—finer than 325 mesh and coarser than 2 microns.
-2μ—finer than 2 microns; principally clay.
A.F.S. clay—clay as defined by the American Foundrymen's Society; finer than 20 microns.
G.F.N.—grain fineness number as defined by the American Foundrymen's Society.

(Concluded)

Mesh size—Percent retained														Sample
20	28	35	48	65	100	150	200	270	325	$+2\mu$*	-2μ*	A.F.S. clay*	G.F.N.*	
4.1	17.9	21.6	25.4	14.1	5.9	1.4	0.9	0.1	0.2	1.7	2.4	2.5	41	2D
0.2	0.2	0.9	10.2	28.3	45.5	10.0	0.3	0.5	0.5	1.4	1.8	2.6	67	2E
			3.8	26.8	32.8	18.7	6.9	0.9	1.8	5.7	2.6	5.6	87	5A
			0.2	6.6	54.3	25.0	3.4	0.9	1.9	4.6	3.1	6.4	88	5B
0.8	6.3	10.1	22.4	31.3	16.3	2.8	2.6	0.2	1.3	4.1	1.4	3.7	58	9A
1.0	9.8	22.7	35.6	14.8	6.1	1.4	1.6	0.0	0.6	2.4	1.6	4.0	42	9B
0.2	3.7	12.7	21.0	31.0	18.4	3.4	0.6	0.2	0.4	4.3	2.2	5.0	54	9C
1.4	5.5	14.5	28.0	19.0	9.3	3.1	1.4	0.4	0.6	5.0	1.6	4.0	51	9D
	0.2	0.1	0.0	4.7	30.0	41.2	14.8	2.2	2.2	2.4	2.2	4.0	102	13A
		0.4	5.1	27.7	45.5	11.2	3.3	0.6	2.1	1.2	2.9	3.7	75	13B
		0.1	0.1	12.0	59.1	15.5	4.4	0.8	1.8	3.7	2.5	4.2	86	13C
			0.2	8.9	59.0	20.4	5.1	0.9	1.6	2.0	1.9	2.6	86	13D
	2.2	7.2	58.0	24.0	3.6	0.2	0.0	0.0	0.0	1.9	2.9	3.6	46	21A
	2.1	8.0	57.5	19.3	5.3	1.5	0.9	0.0	0.0	2.8	2.6	3.6	49	21B
	3.2	9.2	50.9	21.1	6.2	1.7	1.3	0.0	0.0	3.2	3.2	3.3	53	21C
				4.2	28.1	48.0	11.8	1.1	1.5	3.5	1.8	2.8	103	6A
				4.8	42.9	35.2	8.8	1.1	2.1	3.5	1.6	2.4	99	6B
				11.3	66.0	14.2	3.8	0.2	0.4	2.0	2.1	2.4	80	6C
			4.0	32.2	53.5	5.4	2.4	0.0	0.2	0.3	2.0	2.1	66	7A
		0.4	10.2	48.8	30.2	4.9	2.3	0.0	0.2	0.9	2.1	2.1	62	7B
		4.5	35.1	29.8	21.8	4.5	1.4	0.2	0.2	1.0	1.5	1.6	57	7C
		7.0	28.0	38.5	17.3	2.7	1.9	0.2	0.4	2.6	1.4	3.2	56	7D
4.3	10.0	11.5	17.0	19.6	24.6	5.5	2.0	0.4	0.1	3.7	1.3	3.3	56	20A
0.8	6.7	30.3	45.4	8.7	5.1	0.0	0.0	0.0	0.0	1.6	1.4	2.0	40	20B
	1.4	12.4	40.8	31.6	8.9	0.7	1.2	0.0	0.0	1.3	1.7	3.0	46	20C
23.9	33.3	24.9	10.5	2.1	0.6	0.0	0.0	0.0	0.0	2.8	1.9	3.6	26	20D
		0.2	1.3	9.5	25.2	28.7	15.2	3.1	4.5	9.0	3.3	8.8	113	25
0.2	0.2	0.8	11.5	33.3	29.6	8.9	5.4	0.9	2.0	5.1	2.1	6.0	75	11A
	0.4	0.9	13.0	37.8	27.6	6.2	3.8	0.6	1.0	6.4	2.3	3.8	77	11B

Table 5.—Sandstone, Crude Samples

(Analyses by Juanita Witters and L. D. McVicker in the laboratories of the Illinois State Geological Survey)

Sample	Formation	Thickness	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O
						Percent by weight				
2A	Caseyville	73	93.05	.35	1.5	4.2	.06	.07	.00	.09
2B	Caseyville	15	95.21	.41	1.6	1.5	.04	.02	.00	.13
2D	Caseyville	30	92.38	.20	1.8	2.8	.12	1.8	.01	.07
4A, B	Tar Springs	33	97.71	.10	.9	.20	.04	.02	.00	.06
6A, B	Caseyville	38	96.58	.39	1.5	.42	.07	.02	.02	.16
9A, B, C, D	Caseyville	35	96.27	.26	1.8	.60	.07	.02	.02	.16
10A, B	Cypress	23	97.51	.08	1.1	.46	.03	.02	.03	.06
11A, B	Tradewater	54	95.07	.30	2.2	.91	.06	.03	.03	.34
12A, B	Palestine	23	96.38	.30	1.6	.69	.07	.05	.02	.17
15A, B, C	Cypress	44	97.31	.28	1.3	.27	.03	.06	.20	.07
22A, B	Bethel	36	97.54	.16	1.0	.18	.07	.01	.01	.28
23	Hardinsburg	26	97.42	.13	1.0	.46	.05	.03	.01	.15
26A, B	Aux Vases	83	95.54	.48	1.8	.54	.06	.03	.03	.39
27	Degonia	31	92.77	.60	2.6	1.35	.26	.86	.06	.41
29*	Bethel	37	92.47	.40	2.3	.30	.90	2.1	.04	.60
30*	Cypress	50	90.42	.10	3.5	.32	.72	2.9	.10	.44
31*	Hardinsburg	27	87.45	.18	2.3	.90	1.11	4.9	.05	.40
32*	Tar Springs	23	90.74	.18	2.6	1.23	.68	1.6	.03	.45

*Samples from diamond drill core.

3) Washed +270-mesh acid-treated sand with magnetic minerals removed.—Prepared by washing samples in "squirrel-cage" type scrubber, wet-sieving on a 270-mesh sieve, boiling with hydrochloric acid, and removing magnetic particles with a hand magnet. All analytical data were spectrographically determined.

The crude sand, prepared by method 1, shows the chemical composition of the natural unscreened sand. Analyses of samples prepared according to procedure 2 indicate the composition of the +270-mesh sand after washing and scrubbing. Analyses of samples prepared by procedure 3 suggest roughly what reduction in iron and titanium oxides might be expected in the washed +270-mesh sand if it were acid-treated and magnetic grains removed.

The results of the analyses of the natural sandstones, table 5, show considerable variation in composition. Samples 29 to 32 from the diamond drill core are relatively low in silica and high in alumina, magnesia, and lime, which suggests the presence of clay and the minerals calcite (calcium carbonate) and/or dolomite (calcium magnesium carbonate). Most of the other samples appear to contain less clay and no calcite or dolomite, except possibly samples 2D and 27. The three number 2 samples are comparatively high in iron oxide, which was expectable because they were quite yellow or brown.

Table 6 gives analyses of most of the samples in table 5 after they had been thoroughly scrubbed in water and the material passing a 270-mesh sieve discarded. The result of the processing to which they were submitted was to remove clay, some iron oxide, and some fine sand. The percentage of silica in all samples was increased as a result of decrease in the amount of other compounds present. The average amounts of titania, alumina, soda, and lime were decreased about 50 percent. Iron oxide, magnesia, and potassium were decreased an average of about 30 percent. Iron oxide remained high in the number 2 samples, suggesting the presence of particles of iron oxide or grains of clay and iron oxide cemented together that were not disaggregated during scrubbing.

Table 7 shows data on titania and iron oxide in the samples after they had been heated in hydrochloric acid and the magnetic grains removed with a hand magnet. These determinations were made because of the importance of iron oxide in some uses of sand. In all samples the decrease in iron oxide and titania, shown in table 7 as compared with table 6, probably can be expected to be accompanied by an increase in silica content by approximately the same percentage. This is particularly significant for the number 2 samples. As a rule, acid and magnet treatment decreased the iron oxide more than 90 percent below that of the washed samples. Titania was reduced by about 30 percent.

USES OF SANDSTONE

On the basis of laboratory data on outcrop samples alone, it is impossible to state definitely that a given sandstone deposit will constitute a commercial source of sand suitable for a specific use. A great deal depends on the uniformity of the deposit and the amount of processing given the sandstone in preparing it for the market. Further, the specifications of a sand for a given use may vary considerably according to several factors, such as the preference of a consumer and the cost and availability of the sand. In view of this situation and the difficulty of finding satisfactorily detailed specifications for many of the uses of sand, the data that follow should not be interpreted as indicating specific uses for the sand samples prepared from the sandstones of southern Illinois. Rather they point out fields of use that merit investigation as possible outlets for the sands, providing that proper exploration of the sandstone deposits and study of production procedures indicate that the sands can be produced economically. The data also suggest the kind of physical and chemical processing likely to be involved in preparing the sandstones and sands for market.

Because of the availability of sand for structural and similar purposes from the Ohio and Mississippi rivers, it is uncertain whether southern Illinois sandstones ordinarily can be crushed to compete advantageously in the structural-sand market. The best commercial opportunities are probably in the field of silica sand. This will usually involve a processing operation, pos-

Table 6.—Sandstone, Washed +270-Mesh Sand

(Analyses by Juanita Witters in the laboratories of the Illinois State Geological Survey)

Sample	Formation	Thickness	SiO_2*	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O
						Percent by weight				
2A	Caseyville	73	94.29	.20	1.03	4.3	.05	.05	.00	.08
2B	Caseyville	15	98.47	.07	.58	.78	.03	.02	.00	.05
2D	Caseyville	30	96.74	.08	.80	1.3	.07	.94	.00	.07
4A, B	Tar Springs	33	99.34	.04	.34	.18	.02	.02	.00	.06
6A, B	Caseyville	38	98.51	.20	.81	.28	.05	.02	.01	.12
9A, B, C, D	Caseyville	35	98.55	.15	.72	.36	.04	.02	.01	.15
10A, B	Cypress	23	99.13	.05	.47	.25	.02	.02	.01	.05
11A, B	Tradewater	54	98.22	.15	.94	.46	.04	.02	.01	.16
12A, B	Palestine	23	98.08	.28	1.02	.41	.06	.02	.01	.12
15A, B, C	Cypress	44	98.82	.13	.74	.15	.03	.02	.08	.03
22A, B	Bethel	36	98.86	.07	.66	.11	.05	.06	.01	.18
23	Hardinsburg	26	98.63	.12	.79	.32	.04	.02	.01	.07
26A, B	Aux Vases	83	98.30	.10	1.02	.29	.04	.02	.02	.21
27	Degonia	31	96.46	.31	1.51	.63	.16	.51	.04	.38

*By difference.

Table 7.—Sandstone, Washed, Acid- and Magnet-Treated

(Analyses by Juanita Witters in the laboratories of the Illinois State Geological Survey)

Sample	TiO_2	Fe_2O_3	SiO_2*
	Percent by weight		
2A	.080	.053	98.2
2B	.051	.032	99.0
2D	.084	.050	97.5
4A, B	.030	.027	99.5
6A, B	.14	.047	98.8
9A, B, C, D	.058	.032	98.9
10A, B	.020	.019	99.4
11A, B	.10	.045	98.7
12A, B	.13	.076	98.6
15A, B, C	.22	.067	98.9
22A, B	.040	.021	99.0
23	.092	.052	98.9
26A, B	.062	.049	98.6
27	.16	.079	97.1

*Calculated by adding the differences between the percent of TiO_2 and Fe_2O_3 in tables 6 and 7 to the percent SiO_2 in table 6.

sibly a considerable one. No generally accepted definition of silica sand is known, but as a rule it contains more than 95 percent silica; many silica sands contain more than 97 percent silica. As a producer of silica sand commonly markets his sand for a variety of purposes, one of which often is glass sand, many silica sands meet the specifications for glass sand and contain more than 99 percent silica and less than .035 percent Fe_2O_3.

Much silica sand is screened to produce various size grades, although unscreened silica sand of the proper natural grain size is sold for molding sand, furnace sand, and for other purposes. Many silica sands are washed to improve and purify them; some are acid-treated to further increase the percentage of silica content.

The purposes of this investigation have not included extended exploration of the possibilities of improving the quality of the sand produced by crushing southern Illinois sandstone, by washing, acid treatment, and screening. However, the data given on particle size in table 4 show the sizes that can be produced by screening. The chemical analyses in tables 5, 6, and 7 present information on a number of samples in their natural condition; washed; and washed, acid-treated, and magnet-treated. The data provide a basis for preliminary judgment of the effect of various types of processing in upgrading the character of the sand.

POSSIBLE USES OF SANDS SAMPLED

The following discussion relates to the sands produced by disaggregating the samples. More extensive information is required to determine the uses of the deposits themselves.

The samples are classified below in three size groups. The limits of these groups are to some extent arbitrary and were set for convenience.

Fine-grained sands (largely finer than 100 mesh and coarser than 270 mesh).—6A, 8, 13A, 18A, 18B, 25, 27, and 28.

Coarse-grained sands (finer than 4 mesh and largely coarser than 28 mesh).—2A, 2B, and 20D.

Medium-grained sands (largely finer than 28 mesh and coarser than 100 mesh).—all samples not listed above or in the following category are medium-grained.

Between medium- and fine-grained sands.—1A, 1B, 3, 6B, 12A, 12B, 14A, 14B, 24A, and 26A.

Uses thought to merit further investigation, particularly with reference to the market area for southern Illinois sands, are suggested below. There are, no doubt, other possible uses. Many require a carefully screened sand to meet size specifications. Sands containing more iron oxide and less silica than stated possibly can be used for some of the purposes mentioned, but sufficiently detailed specifications are not available to be specific. Structural uses are not included, for reasons previously mentioned.

Whereas the following listing applies especially to the samples tested, it also lays the groundwork for assessing the possibilities of outcrops not sampled. It is assumed that all sands are free, or essentially free, of calcium and magnesium carbonate.

Crude sand samples (table 5) containing more than 95% silica—synthetic molding sand,* possibly furnace-bottom sand.

Washed sand samples (table 6) containing more than 95% silica.

a) Coarse-grained sand—sand-blasting sand, filter sand, possibly synthetic molding sand.

b) Medium-grained sand — traction sand, synthetic molding sand, core sand, sand for surface grinding of plate glass, possibly furnace-bottom sand.

c) Fine-grained sand — synthetic molding sand, possibly glass-grinding sand, possibly furnace-bottom sand, possibly some kinds of glass.

Washed sand, acid-treated, with magnetic minerals removed (table 7); silica 99% or more; iron oxide less than .035%.†

a) Coarse-grained sand — synthetic molding sand, sand-blasting sand, filter sand, stone-sawing sand, sand for grinding to silica flour.

b) Medium-grained sand—glass synthetic molding sand, sand for grinding to silica flour, traction sand, sand-blasting sand (generally coarser than 40 mesh), glass-grinding sand, filter sand, furnace-bottom sand, sand for sand lime brick, sand for chemical purposes such as sodium silicate, carborundum, silicon metal, silicon tetrachloride and silicones, sand for prepared mortars and plasters, catalyst carrier. Possibly fracturing sand; this use ordinarily is believed to require round-grain sand.

c) Fine-grained sand—sand for grinding to silica flour, cement additive, sand for scouring soaps, core sand, molding sand.

*Synthetic molding sand also is referred to as "unbonded" or "formulated" molding sand.

†Samples not meeting these specifications fall into the preceding category.

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